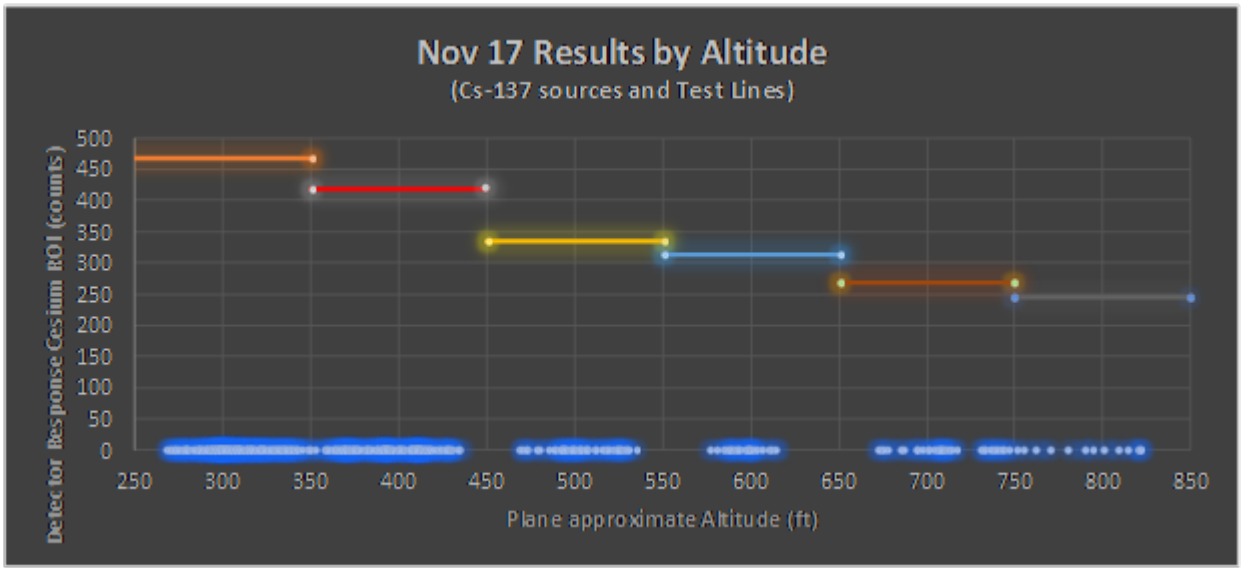
Some observations from the Nevada EPA ASPECT Data Experiment and Functional Exercise

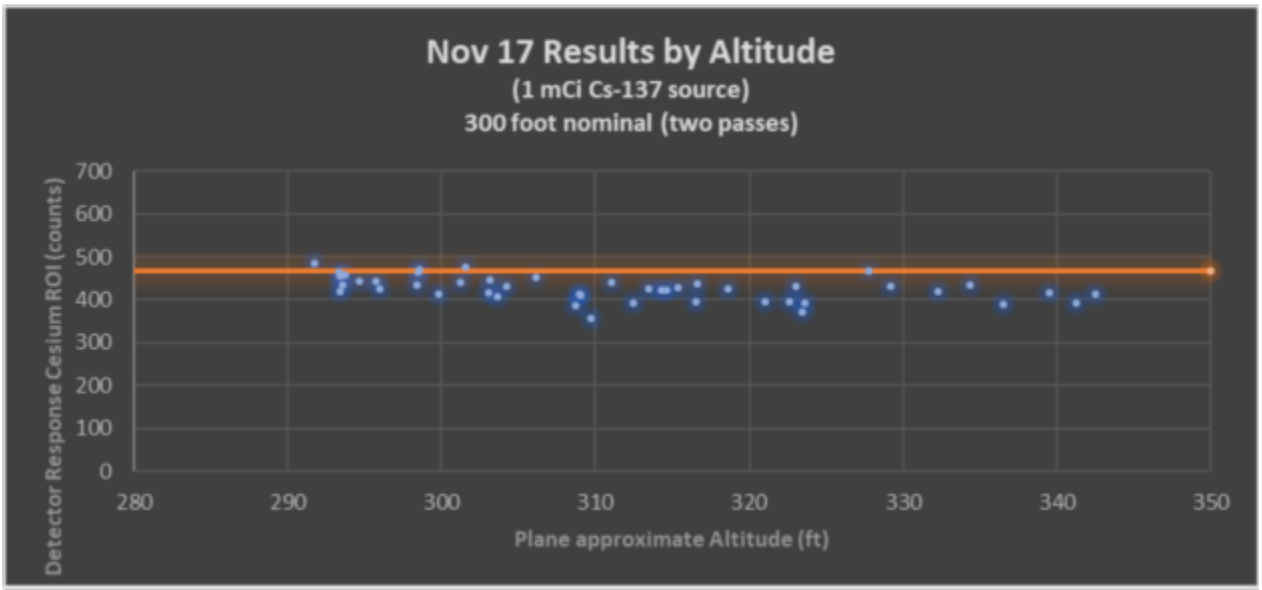
The following are a series of graphs showing the results from the successful flights on November 17, 2021 in the desert near Henderson Nevada. Flights included cosmic data lines, test lines and lines with various sources flown at various altitudes above ground level. The data shown here is from the cesium Region of Interest (ROI) which encompasses channels 200 – 240 corresponding to energies from 600 KeV to 720 KeV. Test lines were run at altitudes ranging from 300 feet to 800 feet and the average of these test lines are shown as lines in the graph covering +/- 50 feet in altitude from the nominal value. Thus the 300-foot test line is shown spanning 250 feet to 350 feet.

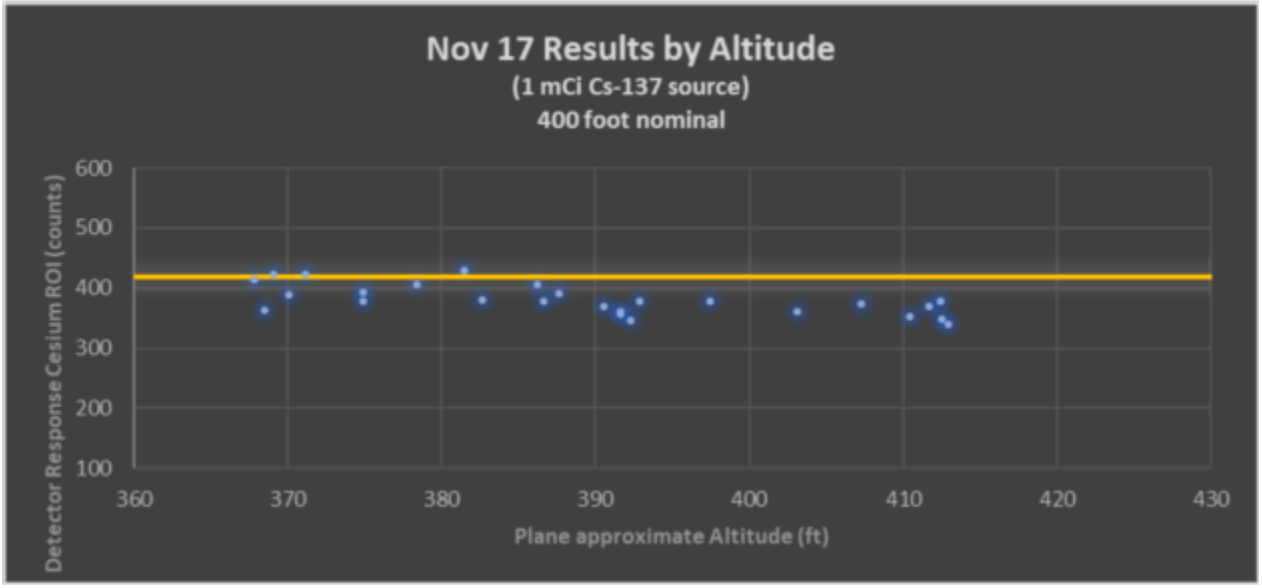


This first graph shows most of the data for the afternoon flight. It does not show the cosmic line that was taken at the beginning of the flight, but test lines are included. For these flights sources were present only for altitudes between 300 and 500 feet. Data from 600 to 800 feet represent only test line data.

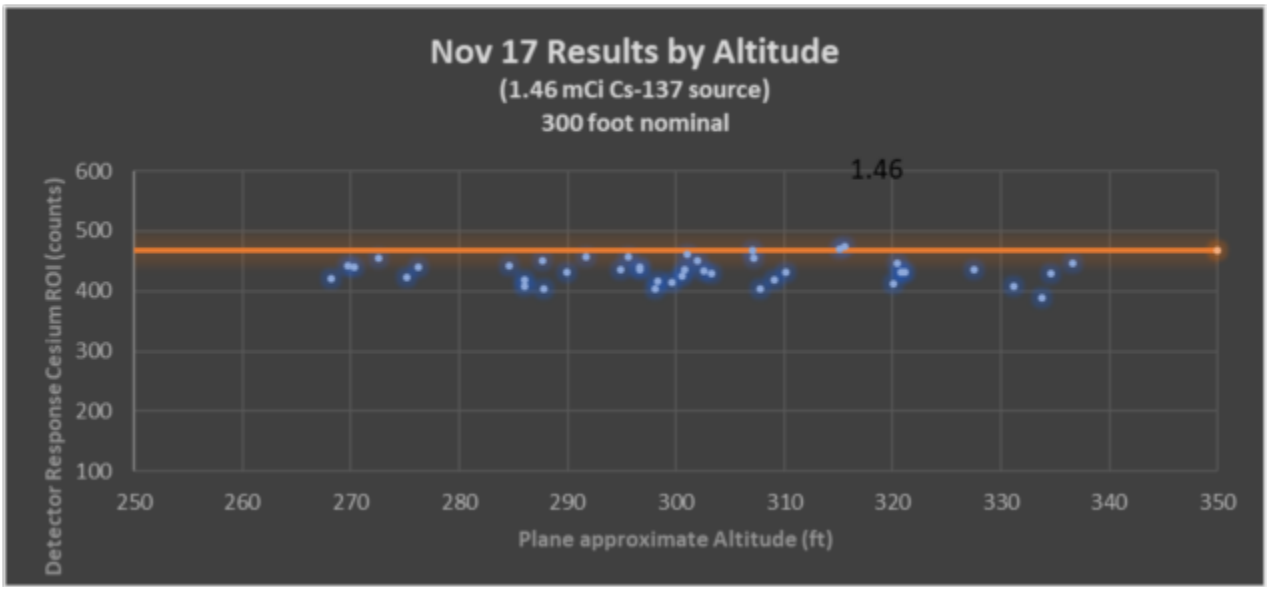
A couple of observations are made. There were clearly detections at 300 and 400 foot levels and likely at the 500 foot level as well. The individual lines are graphed below and show this more clearly. However, the other obvious feature is that the test lines – at least at the lower altitudes – were not particularly good test lines. They did not reflect the average values of the terrain. This is particularly evident at the 300- and 400-foot levels. The test line should appear as an average of the data. The lines depicted here are clearly biased to the high side. This is thought to be the effect of the proximity of the canyon walls but may reflect underlying geologic patterns as well. If this were a mission, it would be prudent to process the data with an alternate survey which better reflects the survey area.

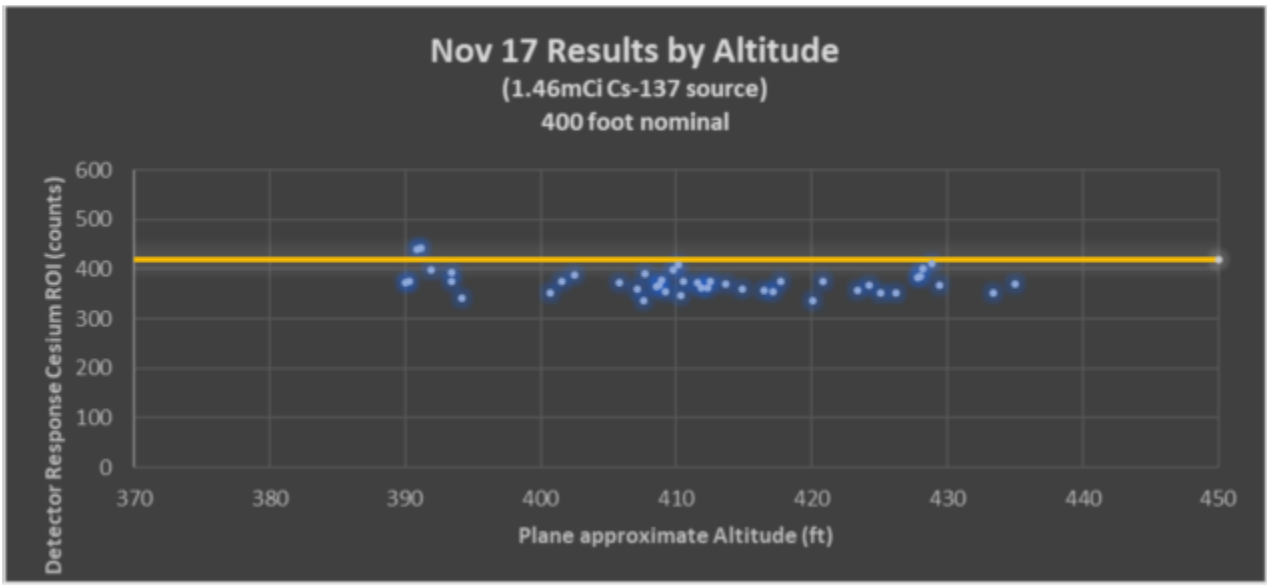
The next set of charts depict three passes of data – two passes at 300 feet and one at 400 feet above a 0.36 mCi source of Cs-137. In none of the flights was this source obviously detected. Keep in mind that the test line (depicted by the solid orange line below) appear to be biased high but still there is no indication of source detection.



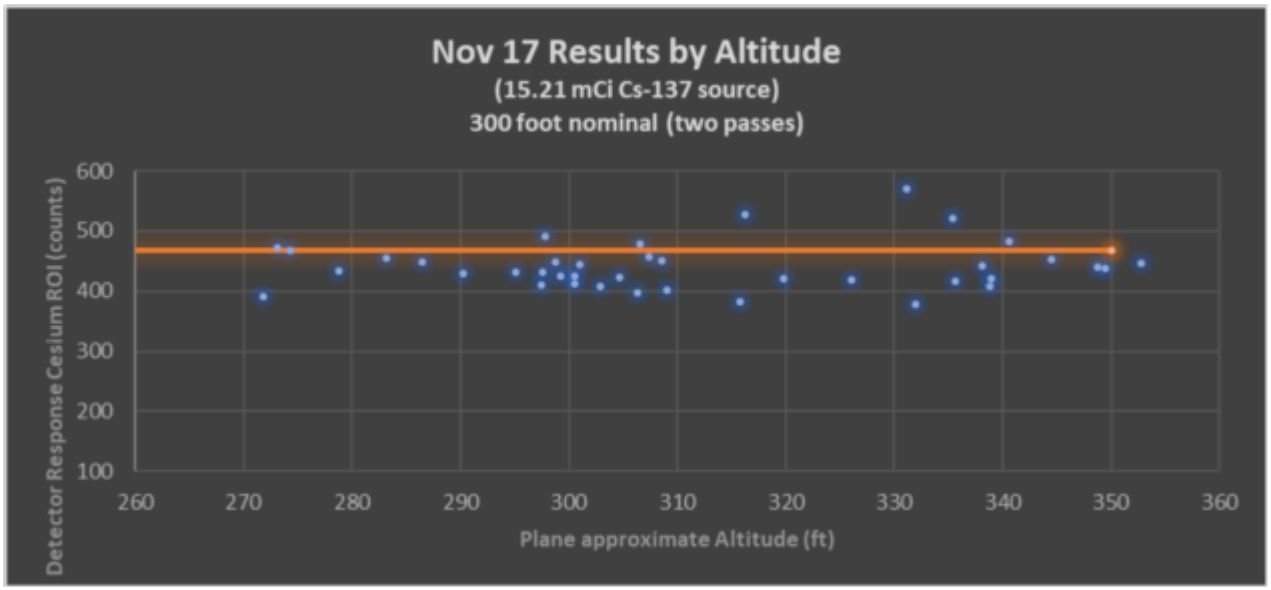


These charts show the response to a 1.46 mCi source with no apparent detections in any of three flights. Test flights still appear to be slightly biased high but the distribution of points does not indicate a potential detection by the system.

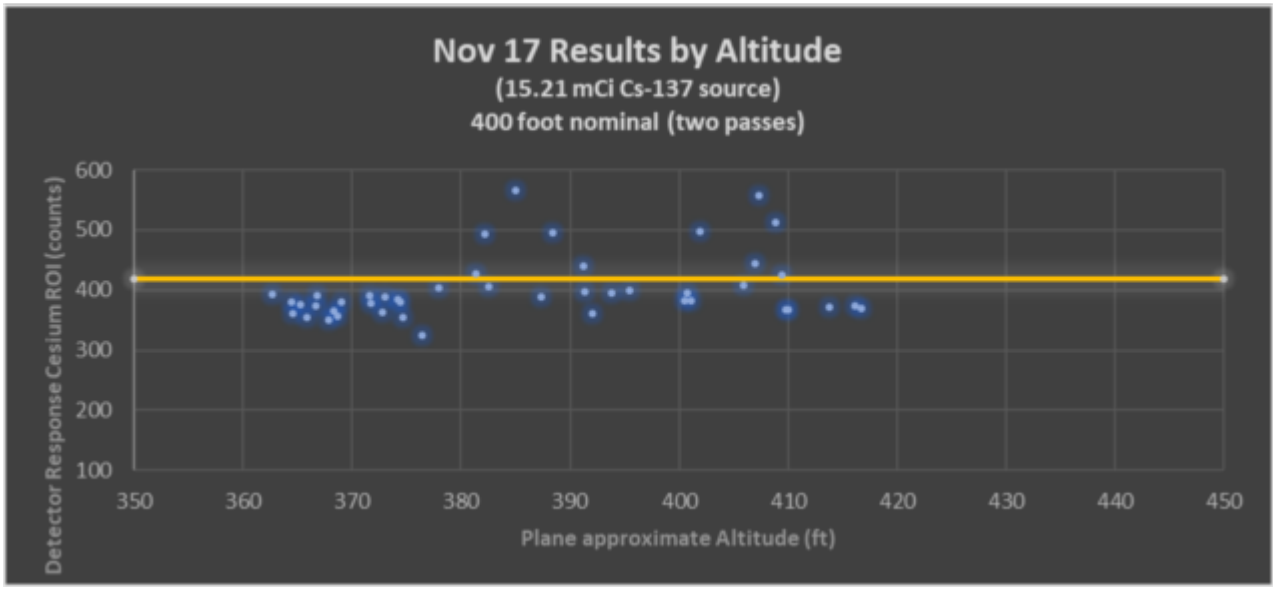




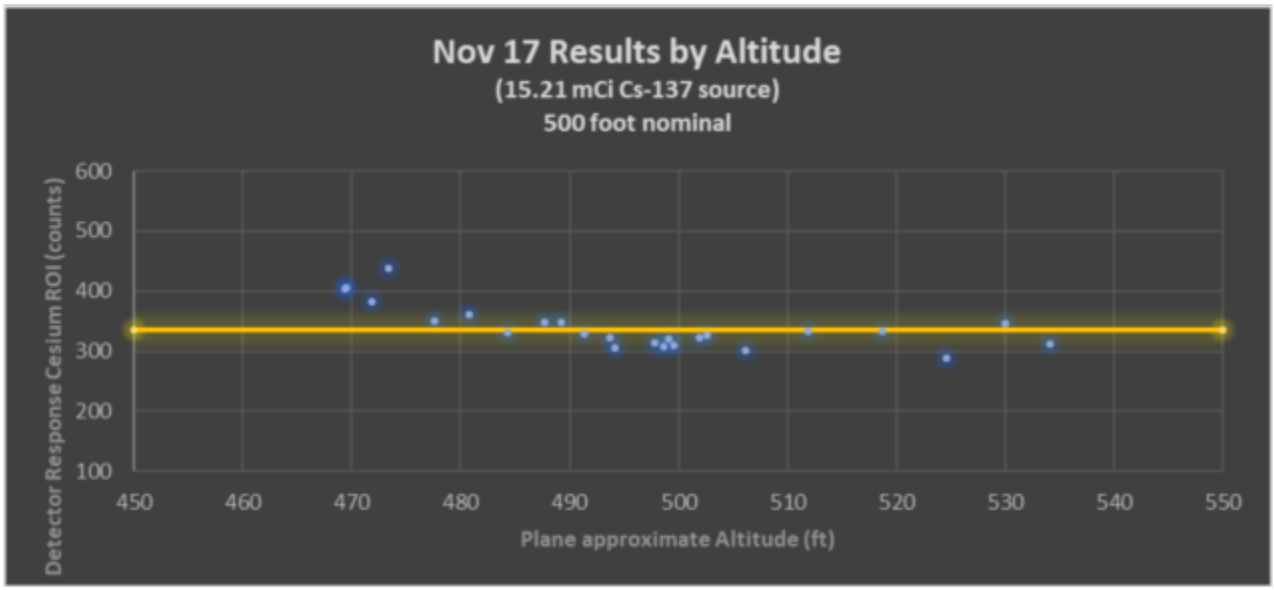
The following charts show the response to a 15.2 mCi source. There are a number of obvious detections at the 300 and 400-foot approaches. Here it appears that the test line bias may be affecting the visual appearance of detections. There may be better detection capability than is depicted at the 300-foot level.



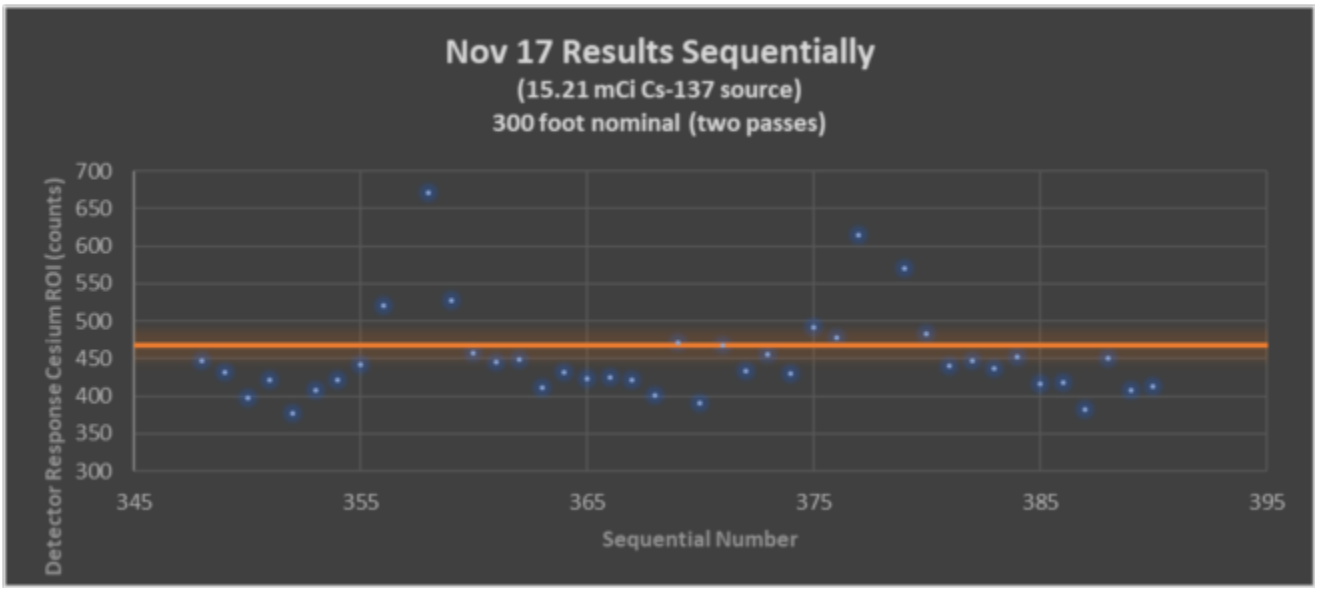
It is interesting to note that the 400-foot line shows apparently better detection than that of the 300-foot line. The cause for this is unclear but likely is a result of rate of change of the solid angle subtended by the detector system combined with a lower background due to altitude.



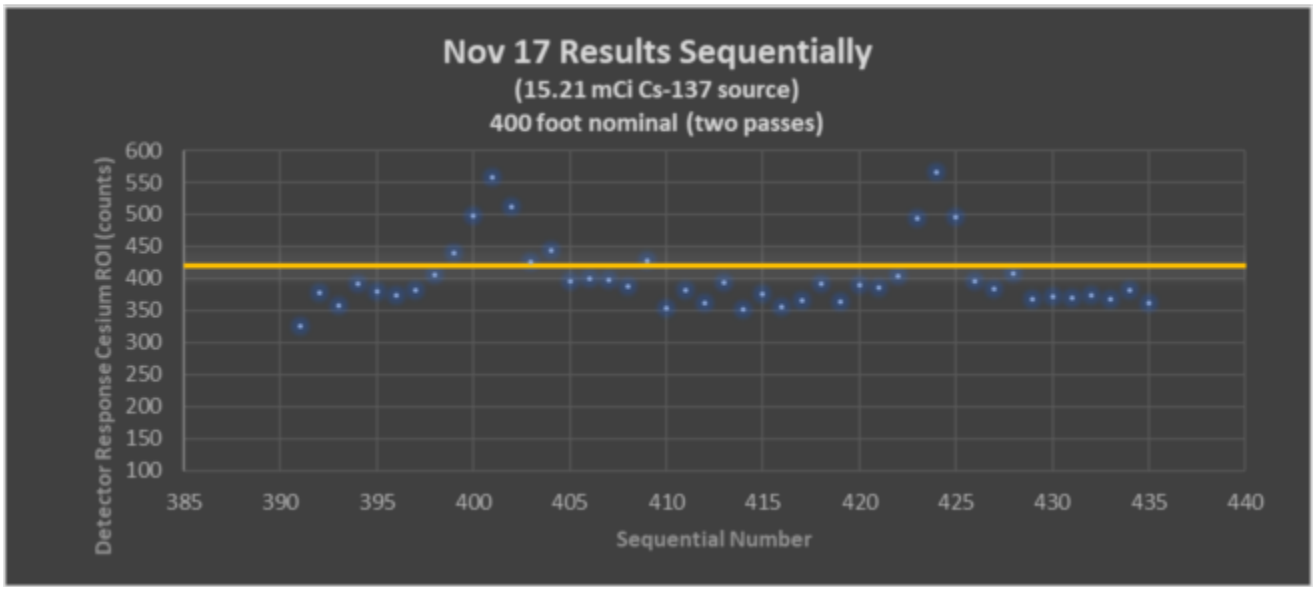
At the 500-foot level, there is still some obvious detection capability, but it is interesting that it occurs at the lower altitudes. This may be serendipitous and a look at the response in time may be instructive.



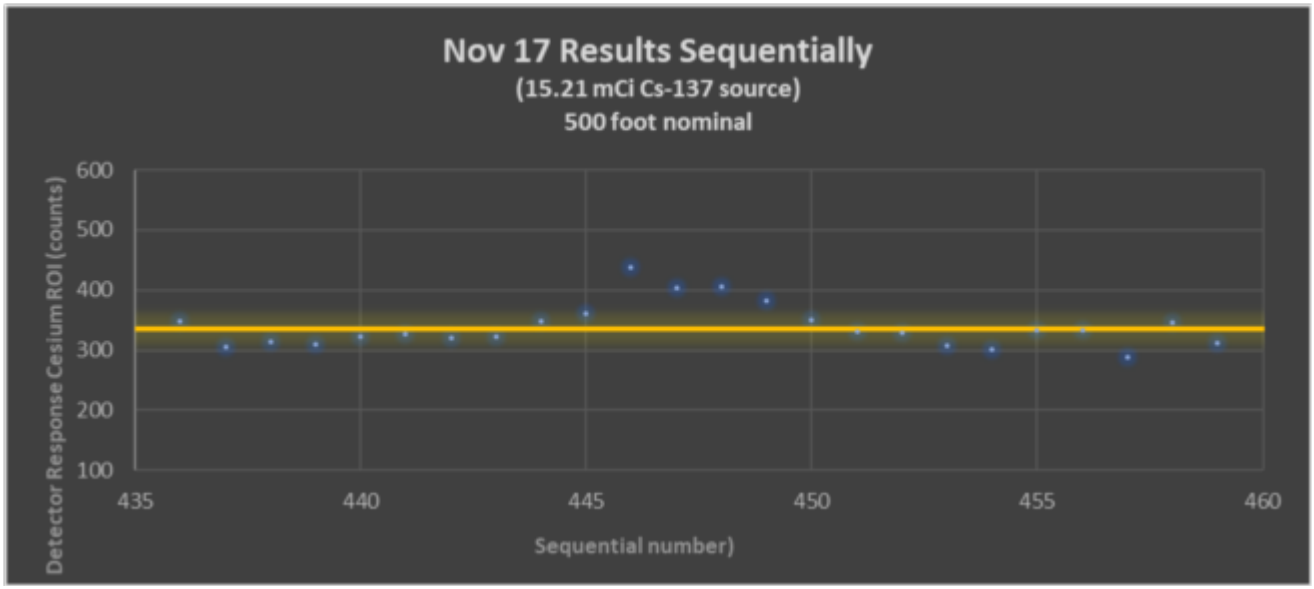
The following data is arranged sequentially in time as the plane approached the target and then receded from it. At the 300- and 400-foot altitudes there are two passes depicted in each graph. Here it is clear that the test line bias is likely masking some positive results, but the approach and retreat of the aircraft relative to the source is evident.



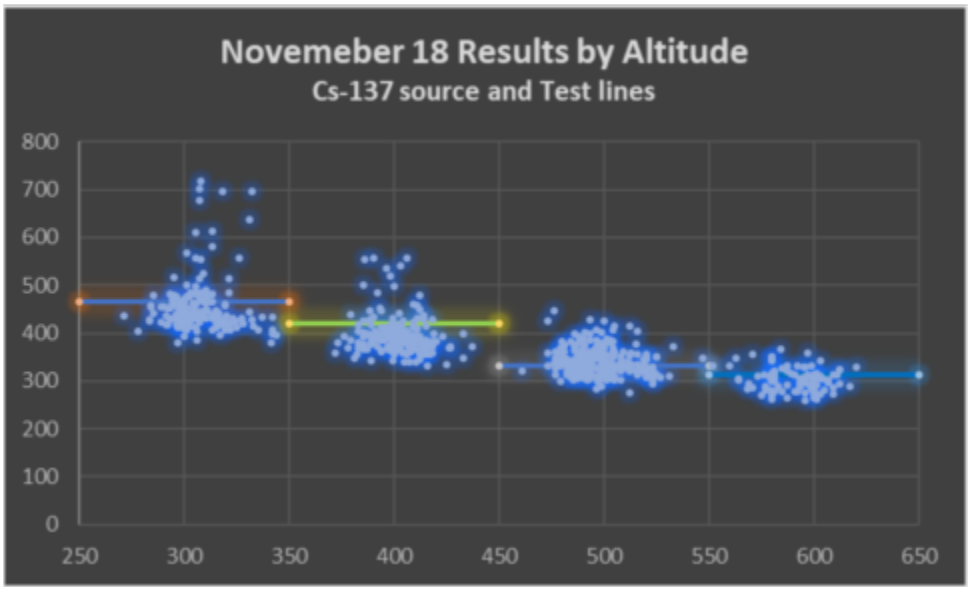
The response at 400-feet altitude is quite symmetric and this may be the appropriate approach altitude for lost source missions. This is an area that could use additional research.



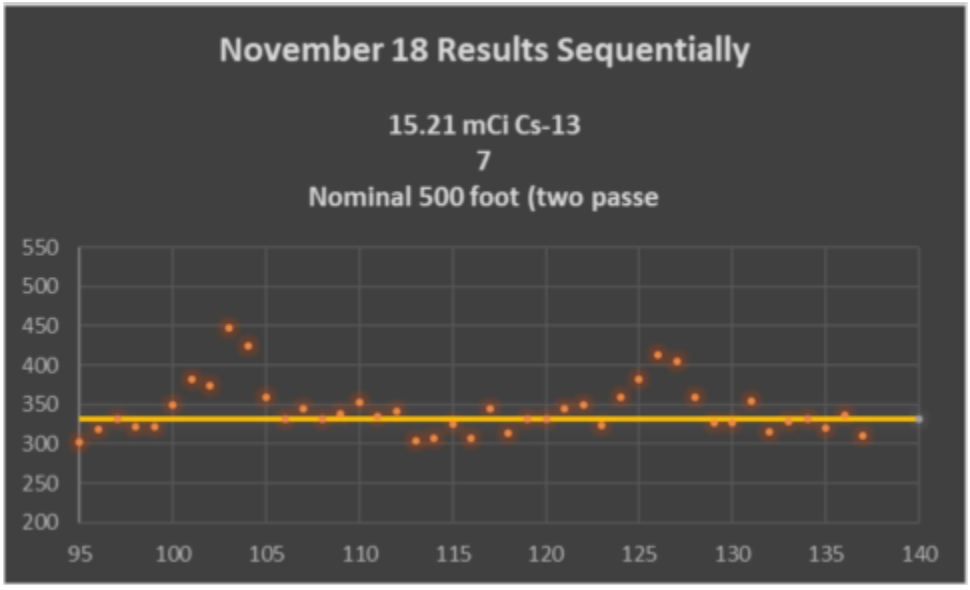
At 500 feet the response is still noticeable but much subdued compared to the 400 foot survey. Although only a single pass was made at this altitude, it shows a relatively symmetric response as well.

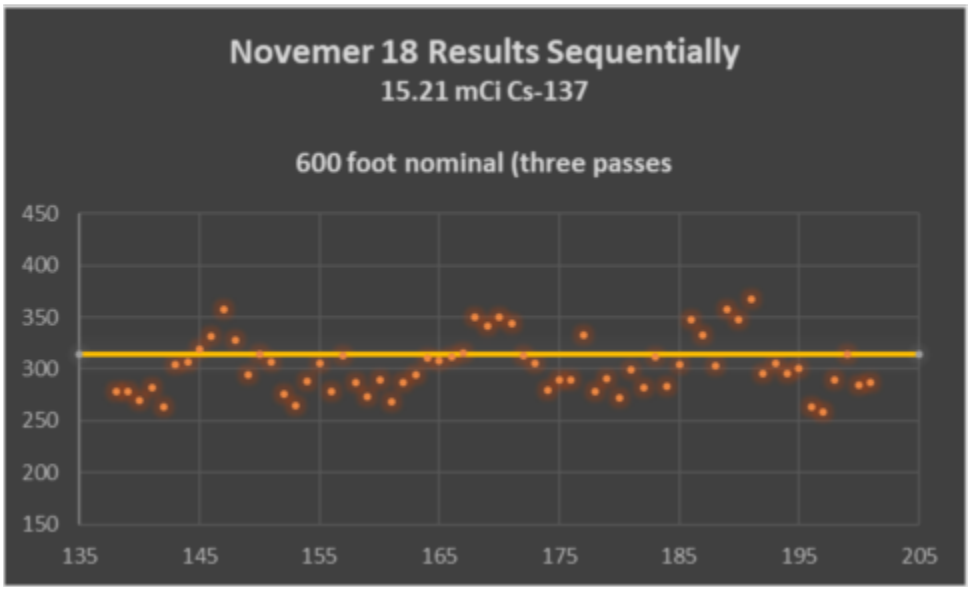


Similar results were tabulated for the November 18 flights. Many of the test lines were not repeated so data was used from the flights on November 17. The results from the 500-foot test line, which was repeated, indicate that the two days agree to within 0.5% so these should be similar for our purposes. Clearly there are indications of positive result at 300 through 500-foot surveys. The test lines continue to appear biased high at the lower altitudes.

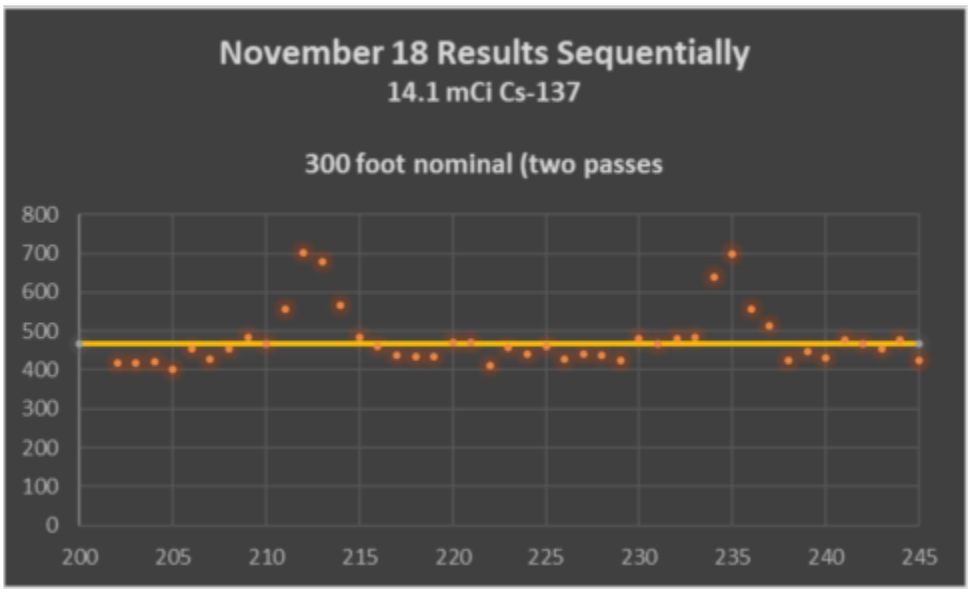


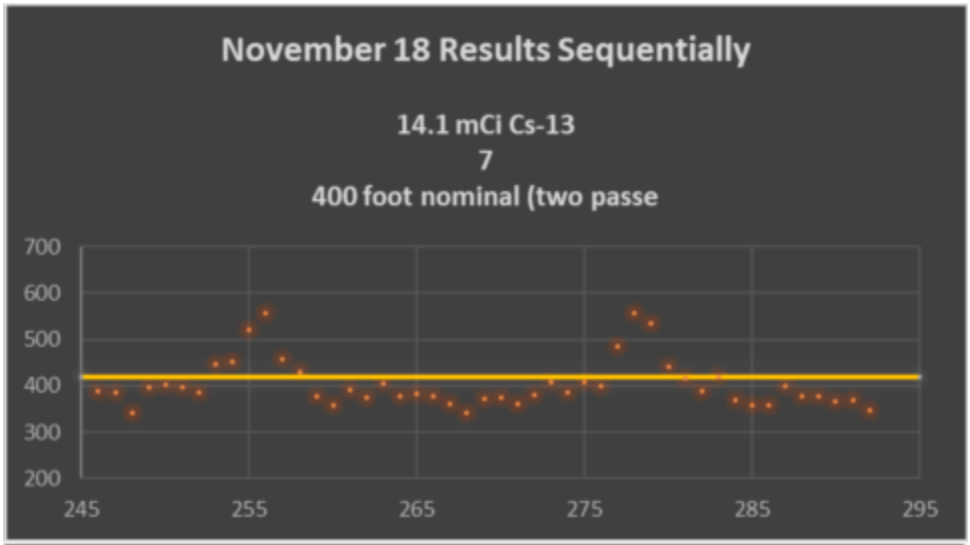
Using the data collected above the 146 mCi sources and using regions of interest on either side of those peaks, an MDA for the 300 foot collection was calculated (using a modified Currie equation) to be approximately 10.5 mCi of Cs-137. The data generated with the 15.2 and 14.1 mCi source collections seem to indicate that calculation is reasonable – although perhaps slightly high. Results at 500 feet over the 15.2 mCi source clearly show a peak in each of the two passes

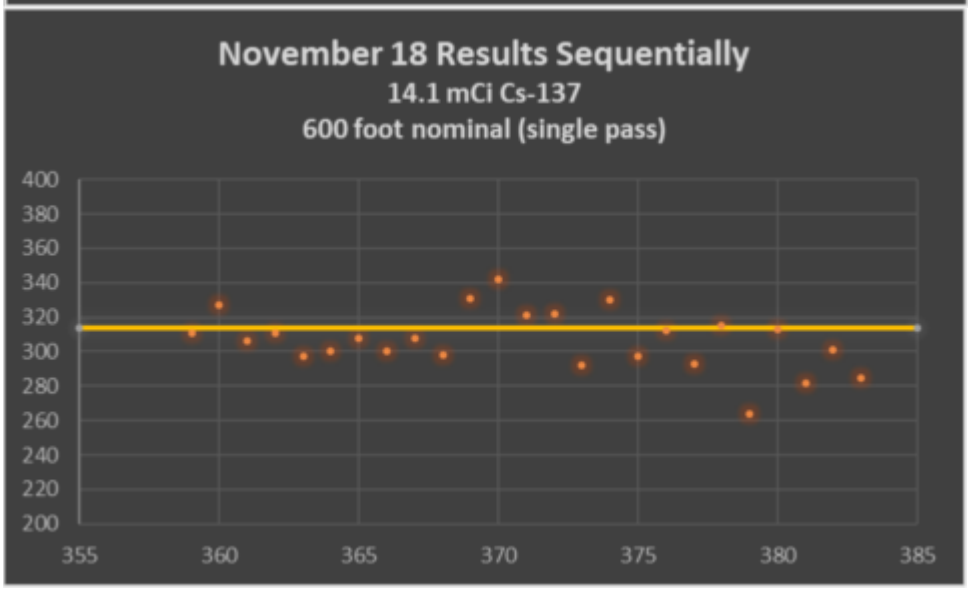




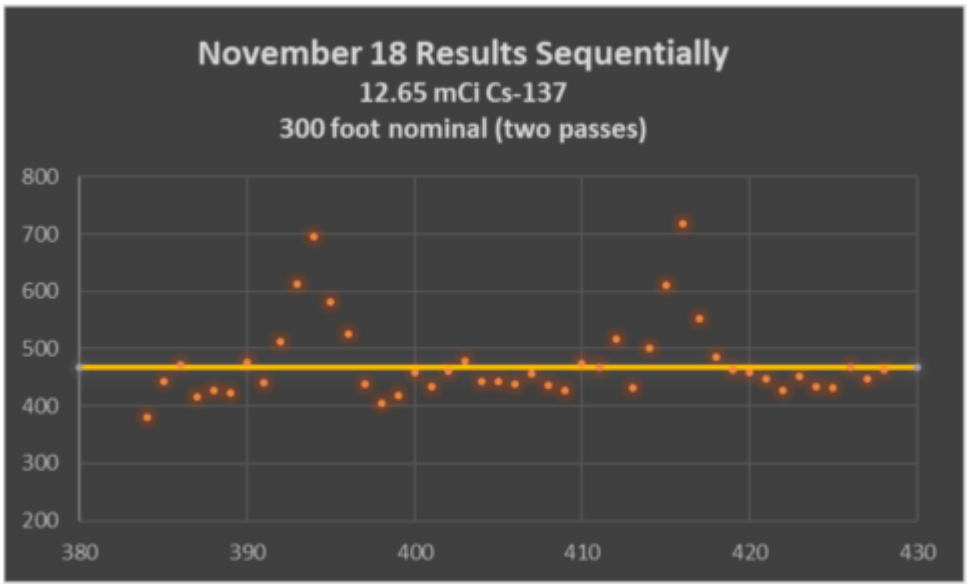
The intent was to get source strengths that were significantly different and well-spaced with regard to activity. As the source certificates were not available until after the exercise was complete, some of the flights occurred over nearly identical activities (nominal values were used in planning not knowing that some of the sources were over 40 years old resulting in significant decay). The next series of flights were completed over a slightly lower activity (approximately 7% lower) and show similar results in terms of detection. Clear detections occur at 300, 400 and 500 feet, while 600 feet is less clear visually.

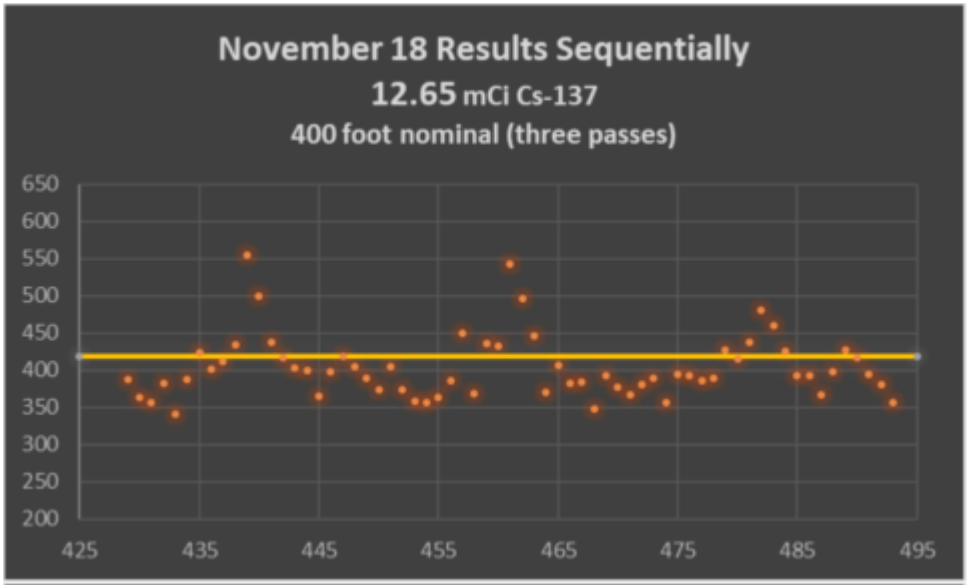


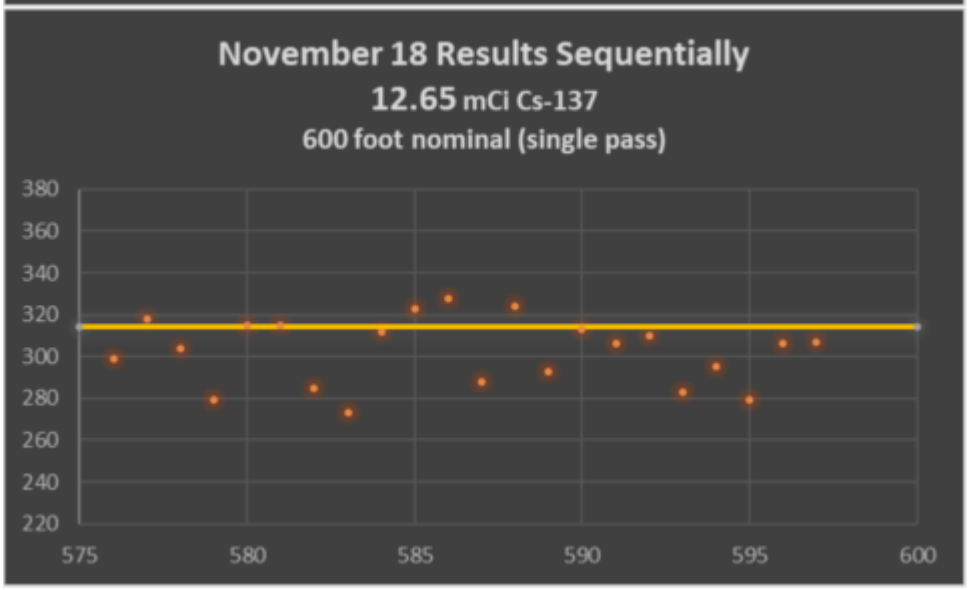




As we proceed down in activity to 12.65 mCi of Cs-137, we still notice clear indications of detection at 300-500 feet, while signal is not really visually discernable at 600 feet.







The equation listed below was used as a first estimate of minimum detectable activity and is taken from an NRC publication for use in gamma spectroscopy. The background value was determined from the 145 mCi flights of day one using ROIs just removed from the high and low energy sides of the photopeak. An average was taken and used as background (B). Efficiency was determined using the highest cesium ROI value and indicates a best case value. Live time, decay factor and sample quantity were set to unity. The abundance (photon yield) was set to 0.85 for Cs-137. The result for a 300 foot AGL survey was 10.5 mCi. It is recognized that a more rigorous calculation may be appropriate e.g. a scanning MDA determination – this was intended to be an approximation and appears to be a good approximation. It should be noted that this determination is not intended, nor appropriate for the pattern recognition protocol. That protocol is expected to have a better MDA value.

$$MDA = \frac{\left(2.71 + 4.65 \times \sqrt{B}\right) \times Decay}{\varepsilon \times b \times LT \times k \times q}$$

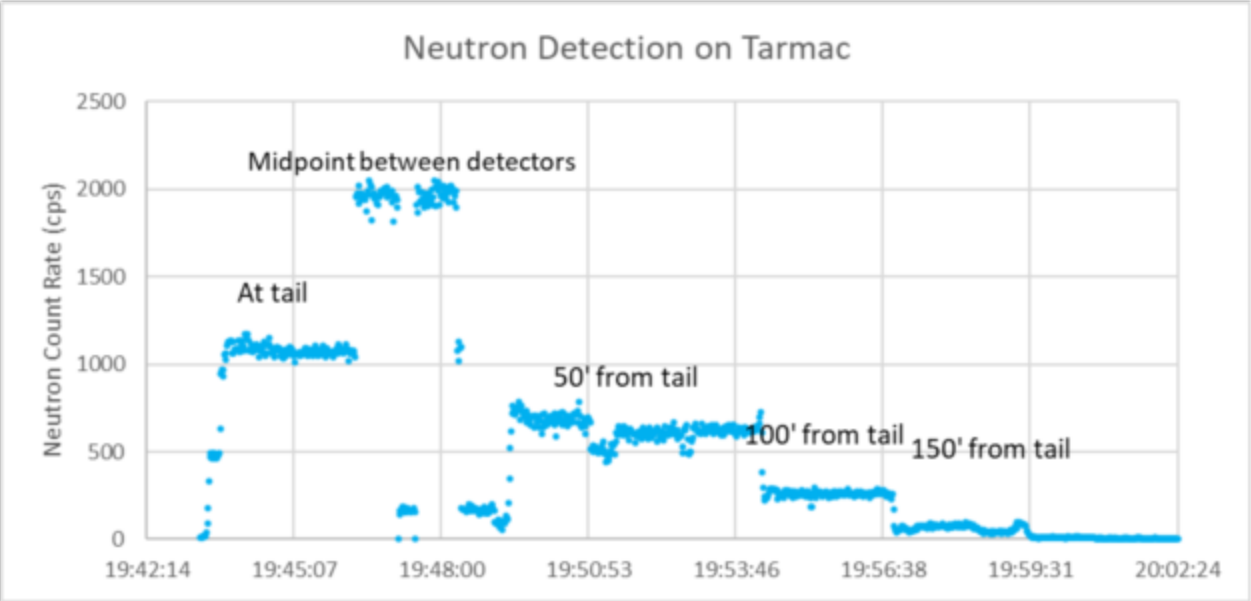
B = Background Sum
Decay = decay factor
ε = efficiency
b = abundance
LT = elapsed live time
k = 3700 dps/μCi
q = sample quantity

The decay corrected source activities were calculated by Carl Palladino (thanks to Carl) based on source manufacturer dates believed to be accurate. Carl is in the process of obtaining source certification forms.

Test	Source(s)	Current Activity (mCi)
1	Cs-137 (400 mCi)	145.82
2	Cs-137 (1 mCi)	0.36
3	Cs-137 (4 mCi)	1.46
4	Cs-137 (22 mCi)	15.21
5	Cs-137 (19 mCi)	14.11
6	Cs-137 (15 mCi)	12.65

The ASPECT uses two moderated Boron Coated Straw (BCS) proportional counters for the detection of neutrons. These detectors were installed in 2014 but had never been tested with a live neutron source. NCRFO provided a 2.89 Ci Americium-Beryllium neutron source for testing. The source was housed in a moderated stainless steel transport shield and placed in the vicinity of the ASPECT aircraft.

Initially the source container was placed at the tail end of the aircraft, near the rear BCS detector. The source remained at the tail of the plane for approximately three minutes before being moved a point approximately midway between the two detectors. The detector response approximately doubled as the source remained in this position for approximately two minutes. The source was then moved to points approximately 50', 100' and 150' from the tail of the aircraft remaining in each position for a short time. Finally, the source was returned to the NCRFO transport vehicle. The graph below depicts the combined detector response during this exercise.


Neutron Detection on Tarmac
Neutron Count Rate (cps)
2500
2000
1500
1000
500
0
Midpoint between detectors
At tail
50' from tail
100' from tail
150' from tail
19:42:14
19:45:07
19:48:00
19:50:53
19:53:46
19:56:38
19:59:31
20:02:24